

Amendments to the claims

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1. (original) A method of fragile watermarking, characterised by the step of generating at least a first ill-conditioned operator, said ill-conditioned operator being related to values extracted from an image or portion thereof A .
2. (original) A method of fragile watermarking according to claim 1 wherein the ill-conditioned operator is generated by altering a value to increase the operator's condition number.
3. (currently amended) A method of fragile watermarking according to claim 1 or 2, comprising the step of replacing a non-zero singular value of a singular value matrix S_A of an image or portion thereof A , with a solution to a linear equation comprising the ill-conditioned operator, wherein the non-zero singular value to be replaced is the smallest non-zero singular value $S_r(A)$ in a singular value matrix S_A of rank r .
4. (canceled)
5. (currently amended) A method of fragile watermarking according to claim 1 any one of the preceding claims, wherein a non-zero singular value of a singular value matrix S_W of a watermark pattern or portion thereof W is replaced, such that said replacement increases the condition number of the singular value matrix S_W of the watermark pattern or portion thereof W , wherein the non-zero singular value to be replaced is the smallest non-zero singular value $S_t(W)$ in a singular value matrix S_W of rank t .
6. (canceled)

7. (currently amended) A method of fragile watermarking according to claim 5~~any one of the preceding claims~~, wherein the step of calculating a replacement non-zero singular value of singular value matrix S_W of a watermark or portion thereof W is calculated by comprises calculating substantially the following equation part:

$$s_t(W) = \varepsilon,$$

where ε is a small positive real number that increases the condition number of the singular value matrix S_W .

8. (currently amended) A method of fragile watermarking according to claim 1~~any one of the preceding claims~~, wherein the step of generating at least a first ill-conditioned operator comprises calculating substantially the following equation part:

$$B = \hat{A}\hat{W},$$

where \hat{W} is substantially constructed according to $\hat{W} = U_w \hat{S}_w V_w^T$, \hat{S}_w comprising at least one altered singular value $s_t(W) = \varepsilon$, and such that B forms a parametric family of matrices

$$B(\hat{s}_r) = \hat{A}(\hat{s}_r)\hat{W} \text{ for possible values of } \hat{s}_r(A).$$

9. (currently amended) A method of fragile watermarking according to claim 8, wherein $\hat{s}_r(A)$ is determined by an L_2 -norm solution of the least squares problem

$\min_{x \in \Re^p} \|Bx - b\|_2^2$ to equal the square of a predefined key N of predetermined value, where b is an arbitrary vector.

10. (currently amended) A method of fragile watermarking according to claim 3~~any one of the preceding claims~~, wherein the step of calculating the replacement non-zero singular value of singular value matrix A is calculated by comprises calculating substantially the following equation part:

$$\min_{\hat{s}_r(A)} \left\{ \sum_{i=1}^q \left(u_{B_i}^T b / s_i(B(\hat{s}_r)) \right)^2 - N^2 \right\},$$

where u_{B_i} is the I-th column of the matrix formed with the right singular vectors of B .

11. (original) A method of fragile watermarking according to claim 10, wherein $\hat{S}_r(A)$ further satisfies

$\hat{S}_r(A) = \bar{S}_r(A) \in [\max(\text{eps}, S_r(A) - \delta), S_r(A) + \delta] = [H_0, H_1]$, where δ is a distortion control and eps is machine precision, such that the step of calculating the replacement non-zero singular value comprises calculating substantially the following equation part:

$$\hat{S}_r \in [H_0, H_1] \left\{ \sum_{i=1}^q \left(u_{B_i}^T b / S_i(B(\hat{S}_r)) \right)^2 - N^2 \right\},$$

with all terms as defined herein.

12. (canceled)

13. (original) A method of fragile watermarking according to claim 12, wherein for a sequential watermarking process comprising the watermarking of portion $A^{(k)}$ after the watermarking of portion $A^{(k-1)}$, $k=1,..,L$ of L portions, then the step of calculating $b^{(k)}$ for portion $A^{(k)}$ comprises calculating substantially the following equation part:

$$b^{(k)} = \begin{cases} A^{(k)} Z^{(k)} & \text{for } k = 1 \\ A^{(k-1)} Z^{(k)} & \text{else,} \end{cases}$$

where $Z(k)$ is a pseudo-random binary vector.

14. (currently amended) A method of fragile watermarking according to claim 1-any one of the preceding claims, wherein the step of calculating a the watermarked image or portion thereof \hat{A} comprises calculating substantially the following equation part:

$$\hat{A} = U_A \hat{S}_A V_A^T$$

where \hat{S}_A comprises at least one replaced singular value, U_A and V_A being left and right singular matrices.

15. (currently amended) A method of fragile watermarking according to claim 1-any one of the preceding claims, wherein a watermark pattern or portion thereof W is generated by a pseudo-random generator seeded by a key K of predetermined value.

16. (canceled)

17. (currently amended) A method of fragile watermarking according to ~~claim 15-either one of claims 15 and 16~~, wherein the-a watermark pattern or portion thereof W is generated by a pseudo-random generator seeded by a key K of predetermined value, combined with either a single or repeated instance of a logo.

18. (currently amended) A method of fragile watermarking according to ~~claim 1-any one of the preceding claims~~, comprising the following steps;

- i. generating a K -dependent watermark pattern W from Ω , or recalling a pre-existing one;
- ii. constructing a parametric family of matrices $B(\hat{S}_r)$;
- iii. estimating a unique parameter $\bar{S}_r(A)$, that minimizes the expression

$$\min_{\hat{S}_r} \left\{ \sum_{i=1}^q \left(u_{B_i}^T b / s_i(B(\hat{S}_r)) \right)^2 - N^2 \right\}; \text{ and}$$

- iv. estimating the watermarked block $\hat{A} = U_A \hat{S}_A V_A^T$ by setting

$$\hat{S} = diag(s_1(A), \dots, s_{r-1}(A), \bar{S}_r(A)).$$

19. (currently amended) A method of fragile watermarking according to claim 1-any one of claims 1 to 17, comprising the following steps;

- i. generating a K -dependent watermark pattern W from Ω , or recalling a pre-existing one;
- ii. constructing a parametric family of matrices $B(\hat{S}_r)$;
- iii. estimating a unique parameter

$\bar{s}_r(A) \in [\max(\text{eps}, s_r(A) - \delta), s_r(A) + \delta] = [H_0, H_1]$, that minimizes the expression:

$$\hat{s}_r \in [H_0, H_1] \left\{ \sum_{i=1}^q \left(u_{B_i}^T b / s_i(B(\hat{S}_r)) \right)^2 - N^2 \right\}; \text{ and}$$

- iv. estimating the watermarked block $\hat{A} = U_A \hat{S}_A V_A^T$ by setting
 $\hat{S} = \text{diag}(s_1(A), \dots, s_{r-1}(A), \bar{s}_r(A)).$

20. (original) A method of verifying a fragile watermark, characterised by the step of generating at least a first ill-conditioned operator by altering a value to increase its condition number, said ill-conditioned operator being related to values extracted from a received image or portion thereof A^* .

21. (original) A method of verifying a fragile watermark according to claim 20, characterised by the step of calculating a solution to the least squares problem

$$\min_{x \in \Re^p} \|B^* x - b\|_2^2 \text{ where } B^* = A^* \hat{W}.$$

22. (currently amended) A method of verifying a fragile watermark according to claim 20 either one of claims 20 and 21, wherein a positive square-root N^* of the L₂-norm solution of the least squares problem $\min_{x \in \Re^p} \|B^* x - b\|_2^2$ is compared with key N ; and

the received image or portion thereof A^* comprising the fragile watermark is declared authentic if $|N^* - N| \leq \tau$, where τ is a threshold value.

23. (currently amended) A method of verifying a fragile watermark according to claim 22
~~any one of claims 20 to 22~~, wherein the step of calculating value N^* is calculated by comprises
calculating substantially the following equation part:

$$(N^*)^2 = \sum_{i=1}^n \left(u_{B_i}^T b / s_i(B^*) \right)^2;$$

N^* is compared with key N ; and

the received image or portion thereof A^* comprising the fragile watermark is declared
authentic if $|N^* - N| \leq \tau$, where τ is a threshold value.

24. (currently amended) Apparatus for fragile watermarking of an image in accordance with
a method of claim 1~~any one of claims 1 to 19~~, and comprising;

generating means for generating at least a first ill-conditioned operator, said ill-
conditioned operator being related to values extracted from an image or portion thereof A .

25. (currently amended) Apparatus for validating a fragile watermarked image in accordance
with a method of claim 20~~any one of claims 20 to 23~~, and comprising;

generating means for generating at least a first ill-conditioned operator by altering a value
to increase its condition number, said ill-conditioned operator being related to values extracted
from a received image or portion thereof A^* .